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(54) **CONFIGURABLE VARIABLE SWEEP VARIABLE SPEED WIPER SYSTEM**

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CPC **B60S 1/0807** (2013.01); **B60S 1/0814** (2013.01); **B60S 1/26** (2013.01)

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See application file for complete search history.

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(57) **ABSTRACT**

A configurable windshield wiper system for a variable sweep angle and/or variable sweep speed. The system includes a bidirectional motor, a gearbox, the gearbox having and input shaft operably coupled to the motor and an output shaft; the gear box configured to ratiometrically step down the number of turns at its output shaft relative to its input shaft; a wiper arm for sweeping a surface of a windshield, the wiper arm operably coupled to an output of the gearbox; and a controller in operable communication with the motor, the controller configured to execute an algorithm to control the position and speed of the motor to

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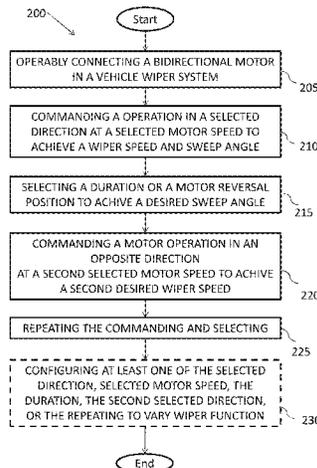
achieve a configured sweep angle and configured sweep speed for the wiper arm.

16 Claims, 4 Drawing Sheets

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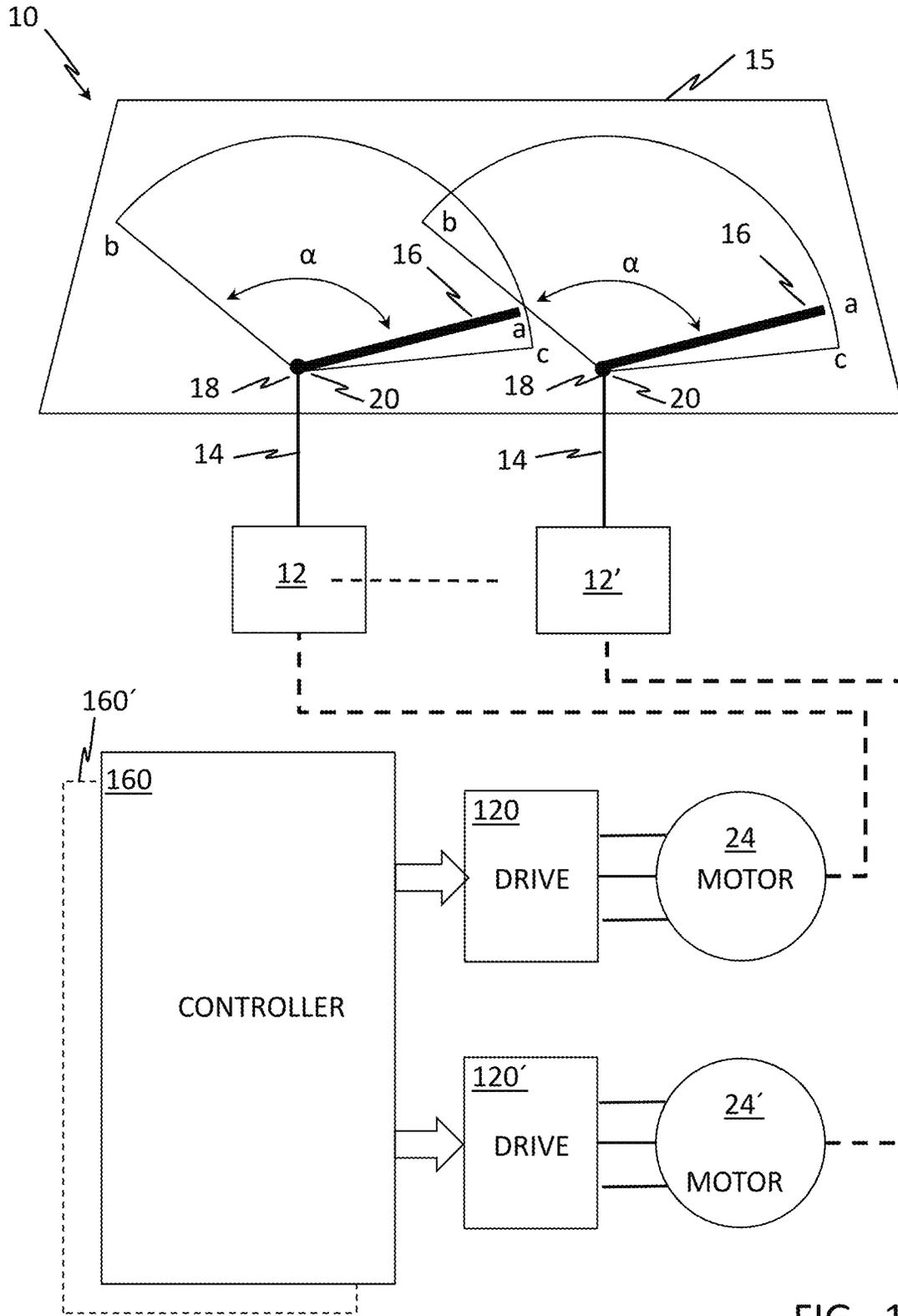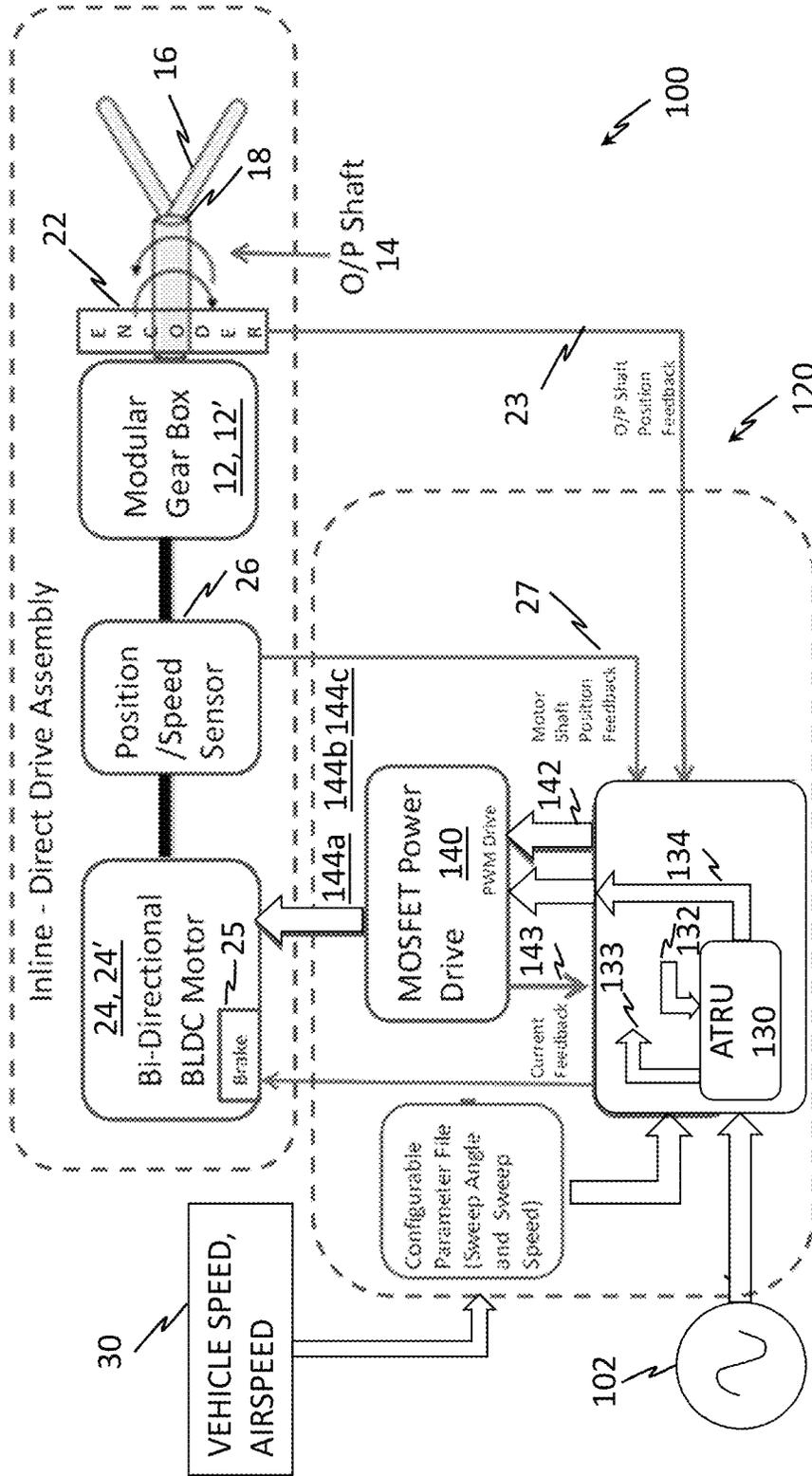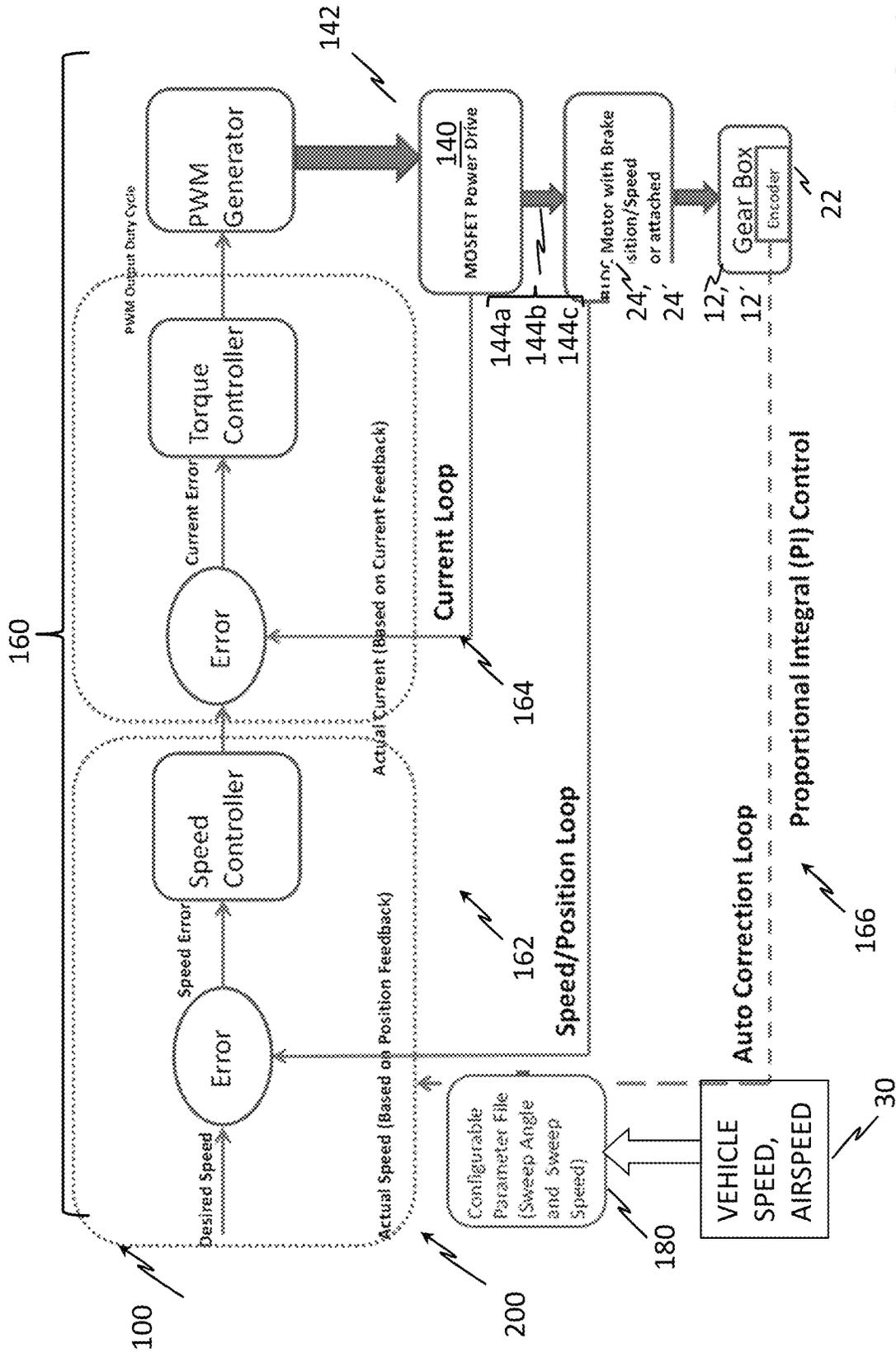
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FIG. 1

FIG. 2

FIG. 3

200

Start

OPERABLY CONNECTING A BIDIRECTIONAL MOTOR
IN A VEHICLE WIPER SYSTEM

205

COMMANDING A OPERATION IN A SELECTED
DIRECTION AT A SELECTED MOTOR SPEED TO
ACHIEVE A WIPER SPEED AND SWEEP ANGLE

210

SELECTING A DURATION OR A MOTOR REVERSAL
POSITION TO ACHIVE A DESIRED SWEEP ANGLE

215

COMMANDING A MOTOR OPERATION IN AN
OPPOSITE DIRECTION
AT A SECOND SELECTED MOTOR SPEED TO ACHIVE
A SECOND DESIRED WIPER SPEED

220

REPEATING THE COMMANDING AND SELECTING

225

CONFIGURING AT LEAST ONE OF THE SELECTED
DIRECTION, SELECTED MOTOR SPEED, THE
DURATION, THE SECOND SELECTED DIRECTION,
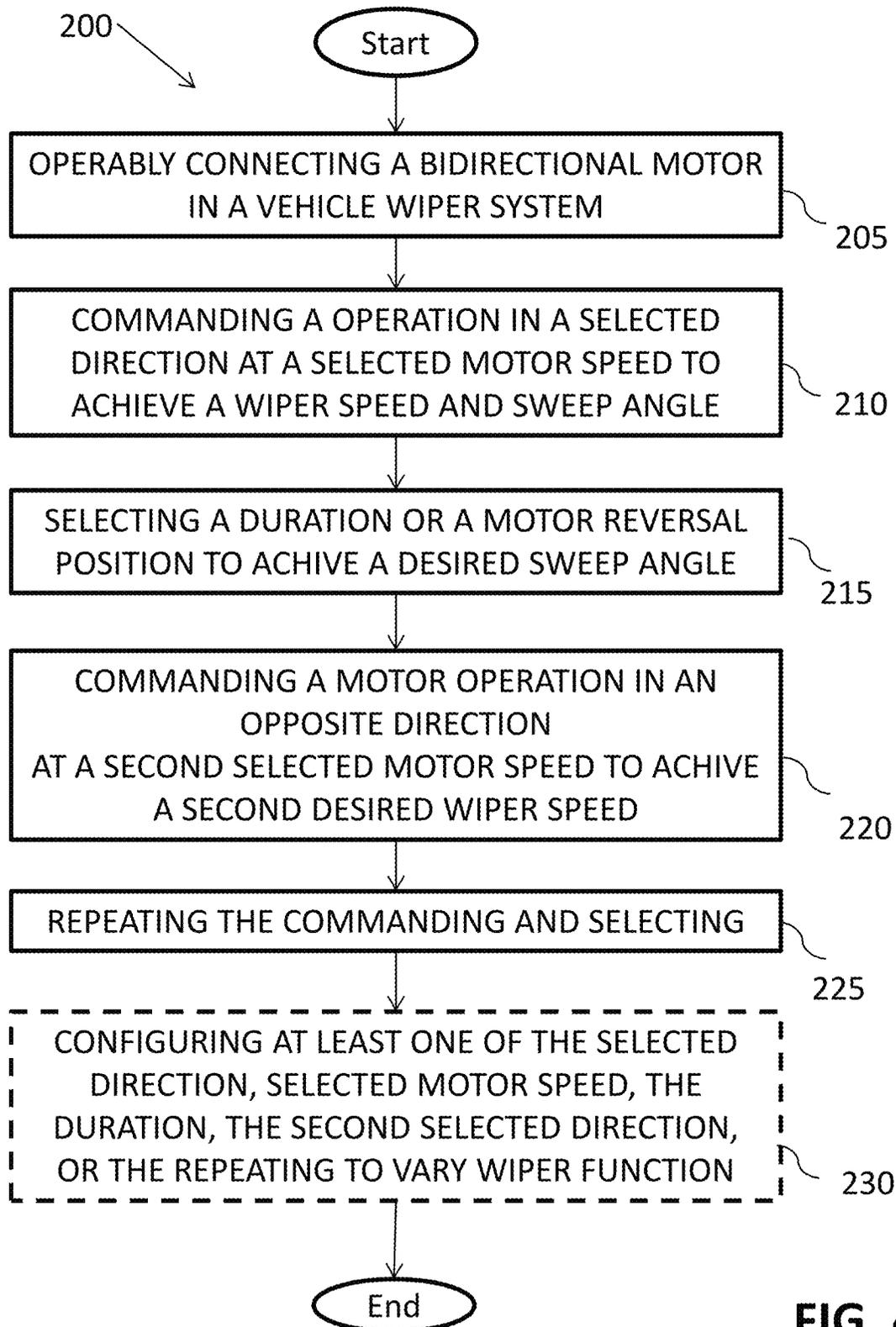OR THE REPEATING TO VARY WIPER FUNCTION

230

End

FIG. 4

CONFIGURABLE VARIABLE SWEEP VARIABLE SPEED WIPER SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 15/872,537 filed Jan. 16, 2018 which claims the benefit of Indian Application No. 201711030390 filed Aug. 28, 2017, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

Embodiments of the disclosure pertain to the art of windshield wiper systems, and in particular, a configurable, variable sweep angle, variable speed windshield wiper system.

BACKGROUND

Windshield wipers are used in a range of vehicles including automobiles, ships, spacecraft, and aircraft. In today's environment, wipers are used to increase the visibility and safety when conditions and precipitation obstruct a vehicle operator's view. Generally wipers have a fixed range for sweeping across the window of the vehicle. The fixed range of motion limits the compatibility with different types of vehicles having different size and shape of windshields. Some vehicles may require a larger sweep angle while others require a smaller sweep angle. Some vehicles may have large windows while others are equipped with small windows.

Present wiper technology commonly utilizes a Brushless Direct Current (BLDC) motor and a gear train with a crank-rocker convertor mechanism. The gear box is used to step down the motor speed and step up the torque at the wiper drive shaft. The rotary motion of the electric motor is converted into oscillatory motion at the drive shaft by the crank-rocker mechanism. Most mechanical systems are constant sweep angle and constant sweep speed mechanisms. A variety of design variants require hardware changes on the crank rocker mechanism to meet the specific sweep requirements for a given platform.

Some systems include variable sweep angles and speed in the wiper system. These systems include a wiper motor coupled to a wiper arm for sweeping a surface of a windshield through a mechanism with several eccentrics, and an indexable eccentric plate. The indexable eccentric plate is used to determine an offset of the wiper arm coupled to the first eccentric to control wiper sweep angle and speed. However, mechanical systems are not as dynamic, with less flexibility than a fully configurable system. Some electronic systems are more configurable and also include regulation and/or profiling of wiper arm speed where a desired/configureable interval corresponding with the preselected speed or speed profile is stored. A pulse-width modulation signal for effecting a speed and interval is employed, preferably with a relatively-low repetition rate. The wiper speed may be profiled to include acceleration and deceleration, and the intervals of acceleration and deceleration may be lengthened substantially to provide an apparent dwell. Some designs and platforms may require even more configurability and flexibility for a given platform, or across a variety of platforms.

BRIEF DESCRIPTION

Disclosed herein is configurable windshield wiper system for a variable sweep angle or variable sweep speed. The

system includes a bidirectional wiper motor, a gearbox, the gearbox having an input shaft operably coupled to the motor and an output shaft; the gear box configured to ratiometrically step down the number of turns at its output shaft relative to its input shaft; a wiper arm for sweeping a surface of a windshield, the wiper arm operably coupled to an output of the gearbox; and a controller in operable communication with the motor, the controller configured to execute an algorithm to control the position and speed of the motor shaft to achieve a configurable sweep angle and configurable sweep speed for the wiper arm.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that the motor is a brushless direct current motor.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that the wiper arm is configured to sweep from a starting point to a reversing point thereby defining the sweep angle.

In addition to one or more of the features described above, or as an alternative, further embodiments may include a position or speed sensor in operable communication with a shaft of the motor, the controller being further configured to control the position and speed of the motor based on at least one of a position and a speed provided by the sensor.

In addition to one or more of the features described above, or as an alternative, further embodiments may include a position or speed sensor in operable communication with the output shaft of the gearbox, the controller being further configured to control the position and speed of the motor based on at least one of a position and a speed of the output shaft of the gearbox provided by the sensor.

In addition to one or more of the features described above, or as an alternative, further embodiments may include a sensor for detecting an operational characteristic of the vehicle in operable communication with the controller, the controller being further configured to control the position and speed of the motor based on the operational characteristic of the vehicle.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that the sensor is an airspeed sensor and the vehicle operational characteristic is airspeed.

In addition to one or more of the features described above, or as an alternative, further embodiments may include; a second bidirectional motor, a second gearbox, the second gearbox having and input shaft operably coupled to the motor and an output shaft; wherein the gear box configured to step down the number of turns at its output shaft relative to its input shaft, a second wiper arm for sweeping a surface of a windshield, the second wiper arm operably coupled to an output of the second gearbox, and the controller in operable communication with the second motor, the controller configured to execute an algorithm to control the position and speed of the second motor to achieve a second sweep angle and second configured sweep speed for the second wiper arm.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that at least one of the second configured sweep angle and second sweep speed for the second wiper arm are different than the configured sweep angle and configured sweep speed for the first wiper arm.

Also described herein in an embodiment is a method of controlling a windshield wiper assembly with configurable variable sweep angle or variable sweep speed in a vehicle. The method includes operably connecting a bidirectional motor in a vehicle wiper system, commanding an operation

of the motor in a selected direction at a selected motor speed, the motor speed selected to achieve at least one of a configured wiper arm sweep speed and a configured sweep angle, and selecting at least one of a duration and a motor reversal position for end of sweep to achieve the configured sweep angle for the wiper arm. After at least one of the duration and reaching the motor reversal position, the method includes directing the motor in the opposite direction at another motor speed, the another motor speed selected to achieve another configured wiper arm speed, and repeating the commanding, selecting and directing. Finally, the method includes configuring at least one of the sweep angle, the sweep speed, the duration, the reversal position and the repeating.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that the wiper arm has a configured starting point and reversal point thereby defining the sweep angle.

In addition to one or more of the features described above, or as an alternative, further embodiments may include controlling at least one of the position and speed of the motor based on a signal from a position or speed sensor in operable communication with a shaft of the motor, providing at least one of a position and speed of the shaft of the motor.

In addition to one or more of the features described above, or as an alternative, further embodiments may include controlling at least one of the position and speed of the motor based on a signal from a position or speed sensor in operable communication with the output shaft of the gearbox providing at least one of a position and speed of the output shaft.

In addition to one or more of the features described above, or as an alternative, further embodiments may include controlling the position and speed of the motor based on a signal from a sensor for detecting an operational characteristic of the vehicle.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that the vehicle operational characteristic is airspeed sensed by an airspeed sensor.

In addition to one or more of the features described above, or as an alternative, further embodiments may include operably connecting a second bidirectional motor in a vehicle wiper system, commanding an operation of the second motor in a second selected direction at a second selected motor speed, the second motor speed selected to achieve at least one of a second configured wiper arm sweep speed and a second configured sweep angle, and selecting at least one of a second duration and a second motor reversal position for end of sweep to achieve the configured sweep angle for the wiper arm. After at least one of the second duration and reaching the second motor reversal position, the method may further include directing the second motor in the opposite direction at a third motor speed, the third motor speed selected to achieve a third configured wiper arm speed. In addition, the method may include repeating the commanding, selecting and directing as well as configuring at least one of the second configured sweep angle, the second configured sweep speed, the second duration, the second reversal position, and the repeating.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that at least one of the second configured sweep angle, the second sweep speed for the second wiper arm, and the third sweep speed are different than the configured sweep angle and configured sweep speed for the first wiper arm.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that at least one of the second configured sweep angle, the second configured sweep speed for the second wiper arm, and the third sweep speed are based on a velocity of a vehicle equipped with the wiper system.

In addition to one or more of the features described above, or as an alternative, further embodiments may include that at least two of the configured wiper arm speed, the another configured wiper arm speed, second configured wiper arm speed for the second wiper arm, and the third configured wiper arm speed are the same.

Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein. For a better understanding of the disclosure with the advantages and the features, refer to the description and to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 depicts a simplified system of a vehicle windshield wiper system as employed in the embodiments;

FIG. 2 depicts a simplified block diagram of a system architecture for the wiper system in accordance with an embodiment;

FIG. 3 depicts a simplified block diagram of a control loop and architecture for the wiper system in accordance with an embodiment; and

FIG. 4 is a flowchart of methods of operating a configurable variable speed or variable sweep angle wiper system in accordance with an embodiment.

DETAILED DESCRIPTION

For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to the embodiments illustrated in the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of this disclosure is thereby intended. The following description is merely illustrative in nature and is not intended to limit the present disclosure, its application or uses. It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features. As used herein, the term controller refers to processing circuitry that may include an application specific integrated circuit (ASIC), an electronic circuit, an electronic processor (shared, dedicated, or group) and memory that executes one or more software or firmware programs, a combinational logic circuit, and/or other suitable interfaces and components that provide the described functionality.

Additionally, the term "exemplary" is used herein to mean "serving as an example, instance or illustration." Any embodiment or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or designs. The terms "at least one" and "one or more" are understood to include any integer number greater than or equal to one, i.e. one, two, three, four, etc. The terms "a plurality" are understood to include any integer number greater than or equal to two, i.e. two,

three, four, five, etc. The term "connection" can include an indirect "connection" and a direct "connection".

As shown and described herein, various features of the disclosure will be presented. Various embodiments may have the same or similar features and thus the same or similar features may be labeled with the same reference numeral, but preceded by a different first number indicating the figure to which the feature is shown. Thus, for example, element "a" that is shown in Figure X may be labeled "Xa" and a similar feature in Figure Z may be labeled "Za." Although similar reference numbers may be used in a generic sense, various embodiments will be described and various features may include changes, alterations, modifications, etc. as will be appreciated by those of skill in the art, whether explicitly described or otherwise would be appreciated by those of skill in the art.

In general, embodiments herein relate generally to configurable variable sweep angle, variable speed wiper system. The wiper system is configurable for a variety of parameters including sweep angle and speed as well as variable as a function of vehicle speed. The embodiments and disclosure are made with reference to an aircraft and helicopter application, however, they can also be applicable to other systems including, but not limited to, vehicles, airplanes, trucks, trains and the like, which rely on a wipers for clearing a windshield and are seeking improved performance over conventional systems. A detailed description of one or more embodiments of the disclosed system, apparatus, and method are presented herein by way of exemplification and not limitation with reference to the figures.

In one or more embodiments, systems, apparatuses, and methods for a configurable and variable sweep angle, variable speed wiper system are provided.

Having a fixed sweep angle may not be suitable for every application. The ability to obtain a variety of sweep angles without the need for custom manufactured parts increases the compatibility of the system with different vehicle and windshield types. A wiper system having a variety of configurations using common parts reduces assembly complexities for manufactures and costs for customers. Moreover, some customers may desire different configurations for different platforms and may desire variable configuration as a function of one or more vehicle operating parameters. In an embodiment, a software configurable drive system to adjust the sweep angle and speed on demand is provided so that a variety of sweep angles, speeds and functions can be realized.

FIG. 1 illustrates a wiper system 10 for a software configurable drive system to adjust the sweep angle and speed on demand. Wiper system 10 includes motor 24 mechanically connected to a gear box 12 (12 and 12' shown for each wiper arm 16, but referred to generally as gearbox 12), each having a least a drive gear (not shown) and a driven gear (not shown). The gear box 12 is coupled to a shaft 14 and then to the wiper arm 16 on a pivot, 18. The pivot 18 may include a bearing mechanism as is known in the art, for example, in an embodiment, a ball bearing 20 is employed. In operation, as the motor 24 moves, in an oscillating (reversing) directions the motion is translated through the gear box 12, the shaft 14 to the wiper arm 16 and thereby cause the wiper arm 16 to sweep through a variable arc "α" on the windshield 15 from a first end of travel "a" to a second end of travel "b". In an embodiment, a speed/position sensor 22 (as shown in FIG. 2) may be employed to measure the position and/or speed of the wiper system 10 and in particular the wiper arm(s) 16. The speed/position sensor 22 may be on any variety conventionally employed.

For example, hall effect sensors, encoders, potentiometers, synchros, resolvers, rotary variable transducers, and the like. In some embodiments a sensor less position determining technique may be employed. The position and/or velocity of the motor wiper arm(s) 16 is provided to the controller 160 for processing as depicted on line 23. In an embodiment, the position and velocity information is utilized by the controller 160 to facilitate controlling the position of the motor 24, 24'. In addition, it may be possible for the wiper system 10 to include a parking position when the motor is and driven such that the wiper arm 16 move to a parking position c. In an embodiment, the wiper system 10 or motor 24, 24' may include a brake 25 (FIG. 2), and/or a braking function. For example, when the motor 24, 24' is not being commanded to move, the brake 25 and/or braking function may be engaged to ensure the motor 24, 24', and thereby the wiper arm 15 does not move. In an embodiment, a single motor 24 may be employed to drive both wiper arms 16. In another embodiment, two substantially independent systems are employed and each wiper arm 16 is controlled with a separate gearbox 12, 12'.

In one or more embodiments, the sweep angle can be integrated with the vehicle velocity. For example, during a heavy snow or rain a smaller sweep angle may be preferred over a larger sweep angle. In addition, while using the smaller sweep angle a faster speed for oscillating the wiper arm 16 may also be utilized. Vehicle velocity may be measured by one of more velocity sensors 30 including, but not limited to airspeed, ground speed, inertial or GPS determined speed and the like. In an embodiment vehicle airspeed is employed though other configurations are possible. In an embodiment, when the velocity of the vehicle, e.g., an aircraft, exceeds a configurable threshold, the wiper system will be operated to provide a smaller sweep angle α, and operated at a higher speed. Speed in this context can include wiper arm sweep speed and/or repetition rate. A signal can be supplied to control the motor 24, 24' to reduce the sweep angle α based on the vehicle/aircraft velocity. In another embodiment, while the vehicle is operated at a velocity less than the configurable threshold, the wiper system 10 will be operated to provide a larger sweep angle α, and a slower speed. In one or more embodiments, the speed of the wipers and the direction affecting the sweeping angles can be independently controlled by an operator.

FIG. 2 depicts a simplified block diagram of a power system 100 and a motor controller(s) or drive(s) 120 for controlling the motor 24, 24'. In an exemplary embodiment, the power system 100 includes an AC power source 102, such as an electrical main line (e.g., 115 Volts AC, 440 Volts AC, 1-phase or 3-phase, primary aircraft bus). The AC power source 102 is operably connected to the motor drive system 120 to provide excitation for the components of the wiper system 10. The AC power from the grid or AC power source 102 is converted to the DC power and then again inverted to the AC power of different frequency and different voltage level for operation of the motor 24, 24'. As described in further detail herein, drive system 120 includes a controller 160 including a rectifier or converter 130 labeled and hereinafter identified as ATRU (auto transformer rectifier unit) 130 to convert the AC power from the AC power source 102 to a DC voltage on a DC bus 134. In an embodiment, the ATRU 130 also includes a voltage level shifting function to change the AC voltage 102 to either a higher voltage or lower voltage. The higher voltage permits establishing a DC bus voltage at a higher voltage than the peak AC voltage of the AC power 102. In some applications the higher voltage is advantageous for motor control appli-

cations. In some applications, a lower voltage on the DC bus **134** is advantageous to reduce the stress on components in the drive **120**. The level shifting function may be implemented by a transformer or conventional active techniques for level shifting. The ATRU **130** may also include a rectification function to convert the level shifted AC power to a DC voltage. In an embodiment the ATRU **130** employs an active rectifier to achieve the rectification function. The ATRU **130** can be an active or passive configuration and may include other functions and features such as active rectification, active or passive filtering for Electromagnetic Interference (EMI) and the like. The drive system **120** also includes a power drive or inverter **140**, to convert the DC voltage on the DC bus **134** formulated by the ATRU **130** to multiphase, AC signals **144a**, **144b**, **144c** to drive the motor **24**, **24'**. Drive signals **144a**, **144b**, **144c** from the drive system **120** are supplied to the motor **24**, **24'** to operate the load e.g., wiper system **10**. In an exemplary embodiment, motor **24**, **24'** includes a multiphase, permanent magnet motor, or more specifically a Brushless DC Motor (BLDC).

As shown in FIG. **2**, the drive system **120** includes ATRU **130** and inverter **140** connected to provide drive signals **144a**, **144b**, **144c** to motor **24**, **24'**. In an embodiment both the ATRU **130** and inverter **140** are controlled by a controller **160**. In an alternative embodiment the ATRU **130** and the inverter **140** are controlled by a separate drive controller, **160** and **160'**, for separate motors **24** and **24'** respectively. Drive controllers **160** (and **160'**) provide control signals **132** to the ATRU **130** to control operation of the ATRU **130** and generation of the DC voltage on the DC bus **134**. In another embodiment, as shown in FIG. **2**, the ATRU **130** is embedded with and integrated with the controller **160** (Shown in FIG. **3**). The ATRU **130** may provide several sensor signals to the controller **160**, **160'** to facilitate level shifting the AC voltage from the AC power source **102** as well as rectification and generation of the DC voltage on the DC bus **134**. The sensor signals **133** may include information of the active rectification in the ATRU and the switching devices as conventionally employed to facilitate the rectification. The sensor signals **133** may include, but not be limited to status of the switching devices, operation of the switching devices, temperature of the switching devices, and the like.

Likewise, the controllers **160** (and **160'**) provide control signals **142** to the inverter **140** to control generation of the drive signals **144a**, **144b**, **144c** to motor **24**, **24'**. The inverter **140** may provide several sensor signals **143** to the controller **160**, **160'** to facilitate generation of the control signals **142** to the inverter **140** and ultimately the motor drive signals **144a**, **144b**, **144c**. Sensor signals from the inverter **140** may include information of the operation of the switching devices employed to facilitate the pulse width modulation (PWM) generation of the motor drive signals **144a**, **144b**, **144c**. Sensor signals **143** may include, but not be limited to status of the switching devices, operation of the switching devices, temperature of the switching devices, bus current, and the like. Drive controllers **160**, **160'** may be implemented using a general-purpose microprocessor executing a computer program stored on a storage medium (memory) to perform the operations described herein. Alternatively, drive controllers **160**, **160'** may be implemented in hardware (e.g., ASIC, FPGA) or in a combination of hardware/software.

Drive **120** and the ATRU **130** may further include an as a sensor signal an AC voltage monitor for measuring and monitoring the incoming AC voltage from the aircraft AC power source **102**. The voltage monitor may be any variety of sensor operably connected to the controller **160**, **160'** or just a direct input to the controller **160**, **160'**. In an embodi-

ment, the AC voltage monitor facilitates sensing open phases of the AC power source **102** and over/under voltage of the AC power source **102**. Likewise drive **120** may further include a DC voltage monitor for measuring and monitoring the DC voltage for the DC bus **134**. The DC voltage monitor may be any variety of sensor operably connected to the controller **160**, **160'** or just a direct input to the controller **160**, **160'**. In an embodiment, the DC voltage monitor facilitates sensing over/under voltage of the DC bus **134**.

In addition, drive **120** may further include a DC Current monitor for measuring and monitoring the total DC current for the DC bus **134**. The DC current monitor may be any variety of sensor or sensor operably connected to the controller **160**, **160'** or just a direct input to the controller **160**, **160'** for further processing. In an embodiment, the DC current monitor facilitates sensing over/under current circulating on the DC bus **134**. Finally, drive **120** may further include an output or phase current monitor for measuring and monitoring the individual phase currents for the motor **24**, **24'**. The output current monitor may be any variety of sensor or sensors operably connected to the controller **160**, **160'** or just a direct input to the controller **160**, **160'** for further processing as shown by sensor signals **143**. In an embodiment, the output current monitor facilitates sensing over current or imbalanced currents being supplied to the motor **24**, **24'**.

Continuing now with FIG. **2** for discussion of the operation of the motor drive **120**. In a motor application, operating characteristics for the motor **24**, **24'** such as motor speed, torque, and the like, may be measured and provided to the controller **160** as a feedback signal. In an embodiment a speed/position sensor **26** is employed. The speed/position sensor may be on any variety conventionally employed. For example, Hall Effect sensors, encoders, potentiometers, tachometers, and the like. The position and/or velocity of the motor **24**, **24'** is provided to the controller **160** for processing as depicted on line **27**. In an embodiment, the position and velocity information is utilized by the controller **160** to facilitate controlling the position of the motor **24**, **24'**.

In an embodiment, in operation, to control and drive the motor **24**, **24'**, controller **160** generates voltage reference signal and compares it to the main power voltage feedback signal from the DC bus voltage monitor, to generate a voltage difference signal representative of the difference between them. A voltage feedback proportional-plus-integral (PI) control function is employed and receives the voltage difference signal and converts it to a stable control current reference. Likewise, a current comparator function in controller **160** compares the control current reference with the control current feedback signal to generate a current difference. A control current feedback PI controller function receives the current difference and converts it to a stable control current. A pulse width modulator (PWM) function receives the control current regulating signal and generates corresponding PWM control signals on a PWM control signals **142** to the inverter **140**. The controller regulates the PWM control signals **142** to produce a level of the control current responsive to the voltage feedback and a control current feedback functions. In an exemplary embodiment, the controller **160** executes a method for controlling the position or speed of the motor **24**, **24'** as needed to control the sweep angle and speed of the wiper arms **16** as will be described further herein. Under normal operation, the inverter **140**, based on the PWM control signals **142** generates phase excitation control signals **144a**, **144b**, **144c** applied to the motor **24**, **24'**.

To that end, in an embodiment, the controller **160** executes a method **200** (See FIG. **4**) of controlling the wiper system **10** operation and more particularly to precisely control the positioning and speed of the motor **24, 24'** and thereby the wiper arm **16**. In an exemplary embodiment, a control scheme is employed and a system architecture is implemented that includes proportional integral (PI) controlled bi-directional operation and control of the motor **24, 24'**. Position/Speed sensor **26** at the motor **24, 24'** and/or gear box **12,** (**12'**) is employed to produce variable sweep area/angle, sweep speed at the gear box output shaft **14** and ultimately drives the wiper arm **16** assembly as shown in FIG. **1**. It should be appreciated that integral control is implemented with proportional control to facilitate reductions in the steady state error/offset that may otherwise be result with proportional control alone.

In operation, use of BLDC motor **24, 24'** with bi-directional control, (i.e., use as a reversible motor), eliminates the conventional mechanical linkages and four bar mechanism of conventional wiper systems. In an exemplary embodiment, when controlled as described herein the motor **24, 24'** rotates in a first direction and then is reversed after a selected number of revolutions, to operate in the opposite direction. The point of reversal (point "a" or "b" as shown no FIG. **1**) of the motor direction depends on the desired/configurable sweep angle α, sweep speed, and the gear ratio of the gear box **12, 12'**. For example, in one embodiment, the number of motor revolutions per reversal is equal to the sweep angle α multiplied by the gear ratio/360. Furthermore, the motor speed is equivalent to the external wiper speed multiplied by the gear ratio. The rotational angle control depends in part on the configuration and design of the motor **24, 24'**, more particularly, the number of poles in the motor **24, 24'** and number of stop positions the motor **24, 24'** can support. For example, considering an existing configuration of an 8 pole motor **24, 24'** with **24** stop positions, such a configuration would produce a position tolerance of 15 degrees at the shaft of the motor **24, 24'**. This would then correspond to sweep angle tolerance of (15/gear ratio) of the gear box **12, 12'**. Therefore, the gear ratio in the gearbox **12, 12'** may be selected to achieve the desired/configurable motion. For example a gear ratio of 100 would result in a speed reduction of 100 and a resolution on wiper arm position of 0.15 degrees. It should be appreciated that the sweep speed in one direction may be different than in the other direction. That is, the sweep speed from "a" to "b" may be different than the sweep speed from "b" to "a". Moreover, in some embodiments multiple motors **24, 24'**, gearboxes etc. may be employed to drive multiple sets of wipers. In this case it should also be appreciated that the sweep speeds and sweep angle α for one motor **24, 24'** may differ than those for another motor **24, 24'**.

Turning now to FIG. **3** as well, where a high level control block diagram is depicted for the wiper system **10**. In an embodiment, the control loop may be executed as part of a methodology or process **200** (FIG. **4**) in the controller **160, 160'**. In an embodiment, as depicted in FIG. **3**, two control loops are depicted. A speed/position feedback loop **162** and a current feedback loop **164** provides input to proportional integral controller to change the duty cycle of PWM pulses to achieve the desired/configurable speed for the motor **24, 24'**. Reversal of the motor **24, 24'** is achieved by reversing the commutation sequence of the motor drive via PWM control signals **142** to power drive circuit and inverter **140**, and thereby changing the polarity and sequencing phase excitation control signals **144a, 144b, 144c** applied to the motor **24, 24'**. Motor speed depends on amplitude of the

applied voltage Amplitude of the applied voltage is controlled by a PWM technique and the voltage of the DC bus **134**. For example, the difference between the actual and desired speed is input to speed controller (PI). Based on this difference, speed controller controls the duty cycle of PWM pulses in the control signals **142**, which correspond to the voltage amplitude of required speed. Motor torque is directly proportional to current. Speed is held to the constant reference value for all load conditions until the full armature current is reached.

Current control loop **164** is implemented as a torque/current controller, which receives as input the speed command from the speed controller loop **162** and another as actual DC Bus current. The torque/current controller controls the duty cycle of PWM pulses. The torque control loop may also monitor the voltage or current of the DC bus **134** as well as the currents of the motor command signals **144a-c**. Additional position feedback from the encoder or position sensor **22** attached at the gear box **12, 12'** output end may be employed to measure the accurate/deviated sweep angle α at the wiper arm **16**. Measurement at the actual wiper arm **16** may be desirable because this parameter may be influenced by, mechanical component tolerances, wear and tear, deflections, hysteresis, and the like, over long life usage of the wiper system **10**. This measured gear box position feedback may also be utilized for the inflight/in-service autocorrection of the sweep area/angle α, using same control algorithms **16**. The algorithm will estimate the error from the position sensor connected on gear box with reference to set sweep area/angle α and revise the set sweep area/angle as α +/- some error value. This further leads to the correction/adjustment of the PWM for getting the desired autocorrected sweep area/angle.

When the motor **24, 24'** is commanded to stop, typically the excitation signals **144a, 144b, 144c** are removed and a power off brake **25** (FIG. **2**) is applied to hold the motor **24, 24'** in the last commanded position. However, because of the electromagnetic energy and kinetic energy in the motor **24, 24'**, the motor **24, 24'** will continue to when deactivated and coast pushing electromagnetic energy back to the drive **120** and DC bus **134** (until the power off brake **25** arrests the motion of the motor **24, 24'** or all the electromagnetic energy in the motor **24, 24'** is dissipated through the inverter **140** and DC bus **134** as well any other components of the drive **120**. This dissipation takes time and actuation of the power off brake **25** also takes time to arrest the motion of motor **24, 24'**. In another embodiment, to address this concern, regenerative braking may be employed to aid in controlling the positioning of the motor **24, 24'** more accurately when desired.

As shown in FIG. **3**, configurable parameter file **180** may be employed to facilitate the configurability of the wiper system and its control. In particular varying the sweep angle α and sweep speed, repetition rate and so on for the wiper system **10**. In an embodiment the configurable parameter file **180** may reside in a separate FLASH memory or into the on chip flash memory of the embedded controller/processor **160** which operating as the motor controller **160**. Based on the configurable parameters of sweep angle α and speed, the position and speed control loop **162** may take selected actions to modify the operating characteristics of the wiper system **10**. For example, in an embodiment, control loop gain & response time for both speed control loop **162** and current control loop **164** may be modified to change the operating characteristics of the system **10**. As a result, the output of the control will drive the PWM pulses of the control signals **132** with desired duty cycle to achieve the

newly configured sweep angle α and sweep speed. Moreover, the wiper system may include onboard variable sweep control to permit variations in the operation of the system 10 by the user or operator. Variable sweep control onboard, i.e., when aircraft is in operation may be achieved using interfaces from the aircraft or vehicle. Such interfaces can include, but not be limited to a communication bus, (e.g., ARINC429 or CAN) which provides the true air speed from relevant vehicle systems 30 wiper system 10. Sweep angle α and speed control logic may be employed with the control loop 162 to map the desired sweep angle and/or speed with air speed, ground speed and the like. Configurable parameter file 180 may include a preselected set of vehicle speeds and respective sweep angle as lookup table burned into the memory. In another embodiment a schedule of constraints may be provided for scheduling sweep angle and sweep speed as a function of vehicle configuration, e.g., type of vehicle, model and the like; vehicle operating parameters such as mode, airspeed, ground speed, and the like; as well as configurations of the wiper system 10. Employing the lookup table data and knowing the air speed information, the control loops 162, 164 of the controller 160 will identify the desired sweep angle at various vehicle speeds, e.g., aircraft air speed. Thus, controller 160 will control the sweep angle α on board based on various vehicle speeds.

Turning now to FIG. 4, a description of the methodology 200 of configurable control of a wiper system 10 in accordance with an embodiment is provided. The method initiates at process step 205 with operably connecting a bidirectional motor 24, 24' in a vehicle wiper system 10. At process step 210 the method 200 includes commanding an operation of the motor 24, 24' in a selected direction at a selected motor speed. The motor speed is selected to achieve a desired wiper arm 16 sweep speed and sweep angle. After a selected duration or motor reversal position from position sensor, the motor 24, 24' is commanded in the opposite direction at a second desired motor speed, once again to achieve a second desired wiper arm 16 speed as depicted at process step 220. The second desired wiper arm 16 speed in second direction may be same or different than the first desired wiper arm 16 speed in first direction. The selected duration or motor reversal position from position sensor is selected to achieve the desired sweep angle α as well as the desired start and stop points "a", "b" for the wiper arm 16 motion as shown at process step 215. Process step 225 includes repeating the commanding steps 210, 220, and the selecting step 215 to define the sweep angle. For example, repeating the sweep every second, every two seconds and so on to provide an intermittent functionality. Finally, at optional process step 230, the selected direction, motor speed, second selected motor speed and interval of the repeating may be configured to vary the function of wiper system 10. For example, one or more of these parameters may be varied for different vehicles, or vehicle characteristics. In an embodiment one or more of these parameters is varied as a function of the vehicle airspeed. For example, providing higher sweep speeds and/or shorter sweep angles as a function of vehicle airspeed, type of precipitation and the like.

In general, technical features of the embodiments herein relate generally to configurable variable sweep angle, variable speed wiper system. The wiper system 10 is configurable for a variety of parameters including sweep angle α and speed as well as variable as a function of vehicle speed. The ability to obtain a variety of sweep angles without the need for custom manufactured parts increases the compatibility of the system with different vehicle and windshield types. Moreover, customization functions facilitate providing customers a variety of configurations for different platforms and vehicle operating parameters. Moreover, the auto configurability permits autocorrected sweep range to account for variations in components over the service life of the wiper system 10.

Other benefits and advantages of the described embodiments include software and remote configuration capability, including minimal or no hardware changes for application to other platforms, improving development time with less cost. The system also facilitates tight, close control on sweep angle tolerances and limits. Another feature of the described embodiments is power savings at high vehicle speeds by onboard change to lower sweep range (onboard variable sweep) as well as torque sensing and control with the speed and current control loops 162 and 164.

The terminology used herein is for the purpose of describing particular embodiments, only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

What is claimed is:

1. A method of controlling a windshield wiper system, the method comprising:
  achieving for a wiper arm a first sweep angle and a first sweep speed in a first direction;
  subsequently achieving for the wiper arm a second sweep speed in a second direction, opposite of the first direction, wherein the second sweep speed is different from the first sweep speed;
  modifying for the wiper arm the first sweep angle to be a modified first sweep angle different from the first sweep angle; and
  repeating the achieving using the modified first sweep angle as the first sweep angle to be followed by sequential repetition of the subsequently achieving and the modifying.

2. The method according to claim 1, wherein the windshield wiper system comprises a brushless direct current motor to drive the wiper arm.

3. The method according to claim 2, wherein the brushless direct current motor is bi-directional.

4. The method according to claim 2, wherein the brushless direct current motor is controllable to execute the method.

5. The method according to claim 1, wherein:
  the first sweep angle is defined by the wiper arm sweeping from a first starting point to a first reversing point, and

the second sweep angle is defined by the wiper arm sweeping from the first reversing point to a second reversing point.

6. The method according to claim 1, further comprising:

sensing at least one of a position and a speed of the wiper arm; and

executing the method in accordance with the at least one of the position and the speed.

7. The method according to claim 6, wherein the operational characteristic is an airspeed of the vehicle.

8. The method according to claim 1, further comprising:

sensing an operational condition of a vehicle in which the configurable windshield wiper system is deployed; and

executing the method in accordance with the operational condition.

9. The method according to claim 1, further comprising:

indirectly sensing at least one of a position and a speed of the wiper arm; and

executing the method in accordance with the at least one of the position and the speed.

10. A method of controlling a windshield wiper system comprising first and second wiper arms respectively driven by controllable first and second bidirectional motors, the method comprising:

achieving for each of the first and second wiper arms respective first sweep angles and respective first sweep speeds in a first direction;

subsequently achieving for each of the first and second wiper arms respective second sweep speeds in a second direction, opposite of the first direction, wherein the respective second sweep speeds are different from the respective first sweep speeds;

modifying for each of the first and second wiper arms the respective first sweep angles to be respective modified first sweep angles different from the respective first sweep angles; and

repeating the achieving using the respective modified first sweep angles as the respective first sweep angles to be

followed by sequential repetition of the subsequently achieving and the modifying.

11. The method according to claim 10, wherein each of the bi-directional motors comprises a brushless direct current motor.

12. The method according to claim 10, wherein:

the respective first sweep angles are defined by each of the first and second wiper arms sweeping from respective first starting points to respective first reversing points, and

the respective second sweep angles are defined by the wiper arm sweeping from the respective first reversing points to respective second reversing points.

13. The method according to claim 10, further comprising:

sensing at least one of a position and a speed of each of the first and second wiper arms; and

executing the method in accordance with the at least one of the position and the speed of each of the first and second wiper arms.

14. The method according to claim 10, further comprising:

indirectly sensing at least one of a position and a speed of each of the first and second wiper arms; and

executing the method in accordance with the at least one of the position and the speed of each of the first and second wiper arms.

15. The method according to claim 10, further comprising:

sensing an operational condition of a vehicle in which the configurable windshield wiper system is deployed; and

executing the method in accordance with the operational condition.

16. The method according to claim 15, wherein the operational characteristic is an airspeed of the vehicle.

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